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COWPEA GENETICS AND BREEDING – A HISTORICAL PERSPECTIVE

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Cowpea (*Vigna unguiculata* (L.) Walp) is the one of most diverse species with highly variable plant morphology, growth habit, maturity, adaptive traits, seed type, seed quality and varied use pattern. The vast genetic variability in cowpea has in turn contributed to numerous genetic studies and good progress in cowpea breeding. A brief history and salient progress is presented below.

Cowpea genetics

The rediscovery of Mendel's paper in 1900, led to a surge in genetic studies in many crops. Cowpea being one of the most variable species attracted attention of many geneticists from the early 1900s. The initial focus through 1920s was primarily on genetics of clearly visible traits such as plant pigments, flower color and seed pigmentation. Subsequently from 1930s to 1960s, inheritance of other plant traits were elucidated followed by genetics of resistance to diseases, insects and other economic traits including quality traits through 1980s and 1990s. Combined over all the documented studies, more than 200 major genes have been identified (Singh 2005) with simple inheritance which control plant pigmentation, plant type, seed type, plant height, leaf type, growth habit, photosensitivity and maturity, nitrogen fixation, fodder quality, heat and drought tolerances, root architecture, resistance to major bacterial, fungal and viral diseases, resistance to root-knot nematodes, resistance to aphid, bruchid and thrips, and resistance to parasitic weeds such as *Striga gesnerioides* and *Alectra vogelii*, pod traits, seed quality traits including protein content, cooking time and mineral contents like iron and zinc grain quality. The specific gene symbols for individual traits have been compiled and tabulated by Fery (1985), Fery and Singh (1997) and Singh 2002).

Cowpea breeding

Sporadic programs on cowpea improvement began from early 1900s resulting in identification of some promising land races and varieties. However, systematic cowpea breeding programs and sustained efforts were initiated from 1960 onwards in a few countries including India, Nigeria, Senegal and USA. Cowpea breeding received a big push and international attention from 1967 onwards after establishment of the International Institute of Tropical Agriculture (IITA) with a global mandate for cowpea research and development. A comprehensive cowpea breeding program was initiated at IITA from 1970 when a critical mass of scientists involving breeders, agronomists, microbiologists, soil scientists, biochemists, food scientists and economists began working as a team in collaboration with national cowpea scientists in Asia, Africa, and Central and South America. IITA subsequently emerged as the center of excellence for cowpea research and it also developed a bilateral cowpea improvement program in many countries including Brazil from 1977-78. Cowpea research received a another boost from 1980 onwards when the USAID funded Bean/Cowpea CRSP (now The Dry Pulses Project) became operational and complemented IITA's efforts in strengthening cowpea research and development in West Africa and East and southern Africa. Since then, the cowpea breeding program progressed over the years in a logical succession. Initially, from 1970 to 1980, the scientists concentrated on collection and evaluation of cowpea germplasm for desirable plant types and disease resistance. From 1981 to 1990, the focus was on breeding for disease and insect resistance combined with desirable seed types for different regions. The major thrust in 1990s was to incorporate resistance to nematodes, and parasitic plants, *Striga gesneriodes* and *Alectra vogelii* combined with drought and heat tolerance, high biological nitrogen fixation and efficient acquisition, use of phosphorus from low-P soils and exploring the possibility of biotechnological interventions for cowpea improvement. Through the support of the Harvest Plus-CIAT/IFPRI Project of CGIAR and rapid developments in biotechnology, concerted efforts in the first decade of the 21st century have been to develop improved short duration cowpea varieties with high protein, iron and zinc suitable for intensive cowpea-based cropping systems to maximize the food production per unit area and per unit time. Simultaneously studies were initiated on cowpea genomics to identify molecular makers to facilitate marker assisted selection for Striga resistance and to develop a Bt-cowpea for resistance to Maruca pod borer.

Cowpea breeding at IITA

The global mandate for cowpea breeding presented a very challenging task to the scientists at IITA because the variety requirements for cowpea differed from region to region in respect of the seed color preference, use patterns, maturity and growth habit and no single variety could be suitable for all countries. Therefore, IITA located additional scientists in Philippines, Nigeria, Niger, Burkina Faso, Cameroon, Congo and Brazil in order to address the regional constraints in cowpea production. IITA scientists began with the identification of major production constraints in different regions in collaboration with the national partners and defined breeding objectives to address the common constraints across several each regions. This was followed by systematic collection, evaluation and screening of over 15,000 cowpea germplasm to identify sources of desirable genes for breeding program. Cheap, reliable and fast screening methods were developed to screen for resistance to major biotic and abiotic constraints and quality traits. Essential field and green house facilities were developed for advancing 3-4 generations each year for fast track breeding and multi-location testing of the selected breeding lines to ensure stable performance over diverse environments. Annual workshops were held with national partners and collaborators and a global network for research, testing and release of the improved varieties was developed. Through the concerted collaborative efforts a large number of improved varieties were developed which have been released in over 60 countries. These include:

Early erect types: This set included varieties with erect plant type and 60-70 day maturity representing different seed colors and seed coat texture. Some of the prominent varieties of this group that have been released and become popular in many countries (Singh et al 2002) are IT82D-752, IT82D-789, IT82D-889, IT82E-16, IT82E-18, IT82E-32, IT83S-818, IT86D-1010, IT93K-452-1, IT97K-1042-3 and IT98K-205-8. These varieties are being grown in short rainy seasons and in multiple cropping systems.

Medium semi-erect types: This set included varieties with semi-erect plant type and 75-80 day maturity representing different colors and seed textures. Some of the prominent varieties of this group that have been released and become popular in many countries are VITA-1, VITA-3, VITA-4, VITA-5, IT84S-2163, IT84S-2246, IT84D-666, IT85F-2020, IT86D-368, IT86D-719, IT87D-697, IT87D-1627, IT88S-574-3, IT89KD-374, IT90K-277, IT90K-372-1, IT97K-368-18 and IT98K-506-1.

Medium- Late semi-spreading types: This set includes photosensitive as well as photo-insensitive varieties which mature between 80 to 100 days and fit as a full season crop in existing cropping systems. Some of the photosensitive varieties are grown as a relay crop in maize-sorghum systems in the West African savanna. Some of the promising varieties in this group that have been released are IT81D-985, IT81D-994, IT89KD-245, IT89KD-288, IT89KD-391 and IT99K-216-38 -1.

Varieties with high protein and micronutrients

The major focus of cowpea improvement programs at the International Institute of Tropical Agriculture (IITA) and other national programs was on high yield and pest resistance through late 1990s even though considerable genetic variability for protein and other quality traits existed in cowpea (Nielsen et al., 1993). It was only through the support of the Harvest Plus-CIAT/IFPRI Project of CGIAR that a systematic research on cowpea quality traits was initiated at IITA in 2003. A total of 50 cowpea lines including promising advanced breeding lines and selected local varieties were grown at IITA Kano Station Research Station, Minjibir, Kano State, Nigeria in 2003 and analyzed for protein and a number of micronutrients. In order to reconfirm these results and study the stability across different environments relevant for cowpea cultivation, the same 50 lines were planted in 2004 at three locations with varying rainfall covering the major cowpea growing regions. From all the plantings, pods were carefully harvested, threshed and packed to avoid soil contamination and these were sent for analysis for total protein and 16 minerals to the Waite Analytical Services, School of Agriculture and Wine, University of Adelaide, PMB1, Glen Osmond 5064, Australia. The analytical results of the first set of 50 lines grown in 2003 showed significant genetic variability for all the attributes and the values ranged between 21 to 30.7% for protein, 545 to 1300 ppm for calcium, 48 to 79 ppm for iron, 23 to 48 ppm for zinc and 12750 to 16150 ppm for potassium. Among these, IT97K-1042-3, IT99K-216-48-1 and IT97K-556-4 appeared to have good levels of all the attributes where as, IT 97K-131-2 and IT86D-724 had the lowest concentration of most of the attributes. The local varieties, Dan Ila and Aloka were intermediate in composition. The results from the second year plantings were consistent with the first year results and the relative ranking of the varieties were very similar. On the basis of individual attributes over the average of two years, IT97K-1042-3 appeared to be the best variety with respect all the quality traits. It had the highest protein (30.7%), iron (69 ppm), zinc (45 ppm), potassium (14378 ppm), magnesium (1987 ppm), phosphorus (5139 ppm) and sulfur (2361 ppm) with above average contents of calcium (858 ppm). The next best lines were IT99K-216-48-1, Dan Ila and IT98K-205-8. IT98D-1399 and Aloka local had the highest levels of calcium.

Performance of the selected cowpea lines in India

Through the continued financial support of the HarvestPlus CIAT/IFPRI Project, the new cowpea varieties, IT97K-1042-3 and IT98K-205-8 with high yield, high protein (28-30%), iron, zinc, calcium were introduced and tested at G.B. Pant University of Agriculture and Technology in northern India for intensive 'wheat-cowpea-rice' cropping system. The average grain yield of these varieties within 60-70 days is about 1.5 ton/ha with complete resistance to yellow mosaic virus. These were also superior in quality traits and food products. Based on their superior performance, IT98K-205-8 was released in the name of 'Pant Lobia-1' in 2008 and IT97K-1042-3 was released in the name of 'Pant Lobia-2' in 2010.The project is making significant progress in developing a set of new varieties with even earlier maturity and better seed quality.

Cowpea Breeding in Brazil

Cowpea breeding program was initiated by The Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária -EMBRAPA)) in 1977 in collaboration with IITA when a Cowpea Breeder was stationed at Goias, Goiania by IITA. Initially, several germplasm lines and improved cowpea varieties were introduced from IITA and evaluated in many parts of Brazil. Some of the promising ones like VITA-3 (EMAPA-822), VITA-7 (EPACE-1) and TVx-3777 (BR-9 Longa) were released for general cultivation which established a good base and stimulated expanded cowpea cultivation as well as catalyzed allocation of more funds for cowpea research by EMBRAPA. A well staffed and very successful Brazilian National Cowpea Breeding Program is now located at Teresina (North-East Brazil) with many regional testing stations. The major focus of is breeding for early maturing varieties with resistance to virus and other diseases along with acceptable seed types. Some of the newly cowpea varieties are BRS- Mazagao (IT87D-1627) and BRS-Potigua (TE96-256-8E). With the release of new cowpea varieties and concerted extension efforts by the Brazilian Government, cowpea production in Brazil has increased from about 267,000 tons in 1980 to over 512,000 tons in 2009. The new short duration varieties are being introduced as a double crop after soybean in the savanna region.

Increased global cowpea production

Thanks to the development and wide spread release of improved short duration high yielding cowpea varieties with diverse plant type and seed type, there has been over 6 fold increase in the world cowpea production in the last few decades – a quiet revolution but greater in magnitude compared to that of cereals and all other pulses (Singh 2010). Based on the available information from FAO and correspondence with scientists in different countries, cowpea annual production has increased from about 0.87 million tons in 1961 to 1.2 million tons in 1981 to 2.4 million tons in 1991 to over 6.3 million tons in 2009. The major increase has been in Niger, Nigeria, Mali, Burkina Faso, Senegal, Tanzania, Uganda, Congo, Myanmar, India and Brazil. The availability of the high yielding diseases and insect resistant varieties with desired seed and growth types and early maturity is quietly catalyzing rapid increase in cowpea-based intensive cropping systems and multiple cropping as well as its extension in non-traditional areas.

Potential of cowpea as the most important legume in the 21st century

Majority of population in the tropics still depend upon food legumes as a source of protein and minerals in their daily diets. However, the production of many food legumes has remained stagnant causing widespread malnutrition from the last 5 decades. This is partly because bulk of the agriculture is now based on the green revolution led cropping systems involving cereals like wheat, rice and maize and food legumes have been pushed to marginal lands and partly because the food legumes like chickpea, lentils, pigeon pea, field pea and beans mature in 120 days or more and compete with cereals for land. It is only cowpea that has a maturity range from 60 to 120 days and its extra-early varieties (60-70 days maturity) fit well as a niche crop in various cereals based cropping systems. This is reflected in the progressive increase of cowpea production from 1961 and much higher in the last decade compared to other pulses. During the last decade cowpea production increased by 73 % while the increase in other crops ranged from zero to 40%. In the wake of increasing global warming and declining rainfall and water table, it is expected that cowpea production will increase manifold in future when 'heat and drought tolerant 60-day cowpeas' become popular as a niche crop in the cereals and root crops systems covering millions of hectares in Asia, Africa and Americas. Northern India alone has about 10 million ha under wheat-rice system. An additional crop of '60-day' cowpeas as a niche crop between wheat and rice can produce between 10 to 15 million tons of cowpea which would double the current pulses production in India. Similar possibility exists for double cowpea cropping in several parts of Africa and wheat-cowpea double cropping in southern United States covering several million ha. Brazil has already added over 150,000 ha in double cropping with soybean and it is also adding thousands of ha of new land each year under cowpea cultivation in the Amazon area. The intensive cereals-cowpea strip cropping and multiple cowpea cropping coupled with the upcoming Maruca resistant Bt- cowpeas would bring a surge in cowpea productivity within the next 10-15 years in Africa.

Future challenges and opportunities for cowpea researchers

To accelerate the pace of increased cowpea cultivation and production in future, there is a need for the cowpea research community to consolidate the gains made in the past and use a combination of conventional and emerging biotech interventions to further develop a diverse set of 'region-specific' and 'niche-specific' cowpea varieties to expand cowpea cultivation in the world and help improve family food security and nutrition. It is also desirable that IITA resumes its global mandate for cowpea research and development and places a few research staff to work with its partners in Asia, Africa and North and South America and Brazil takes a major leadership role in developing and promoting cowpea cultivation in South America.

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